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CAMOUFLAGE APPLICATIONS OF LOW DENSITY URETHANES

AAI Corporation

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TECHNICAL REPORT NO. LWL-CR-22C72

CAMOUFLAGE APPLICATIONS OF LOW DENSITY URETHANES

Final Report
Contract No. DAAD05-72-C-0108
Work Assignment No. 4

By

AAI Corporation
Weapons and Aero Systems Division
P.O. Box 6767
Baltimore, MD 21204

November 1973

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.

U. S. ARMY LAND WARFARE LABORATORY
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13. ABSTRACT
The purpose was to determine feasibility and effectiveness of a new camouflage technique using terrain matching, colored, urethane foam. The foam is sprayed directly on the item for permanent installation or indirectly on a polyethylene substrate cover draped over the item, from which it is readily removed. The items camouflaged are a variety of Army equipment and field installations to disguise, deceive, and confuse the enemy to gain tactical and strategic advantages.

Two commercial spraying machines were employed to apply the foam and to form built-up foam areas to disrupt the item's profile. The urethane is a two-component system, "A" and "B" and these components are segregated in the machines and ultimately mixed in the spray gun nozzle at a 1:1 ratio. The mixed foam can be sprayed on any surface, expands to a 30:1 ratio on contact and solidified in seconds. The light and dark green colors were selected to prove the concept at Fort Hood, Texas, in the summertime. A machine is required for each color and the pigment is added in the "B" component only. The two-colored foam may be applied simultaneously or in sequence. "A" component is the polymeric isocynate and the "B" is the polyol or resin component. The light green background is touched up with irregular dark green areas. Foam sprayed directly on an item is permanent, but can be removed by sandblasting; however, when sprayed on substrate covering the item, it may be readily removed in one piece. In the latter process, the removed foam structural form may be used as a decoy, i.e., bunker or pill box, etc., to confuse the enemy. The sprayed foam provides insulation and waterproofing to the item.

The feasibility and effectiveness of this camouflage technique was successfully proven in "MASSTER" at Fort Hood, Texas and was recommended for Phase II development, wherein the spray machines will be militarized.

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FOREWORD

The work described in this report was conducted for the Applied Chemistry Branch, U.S. Army Land Warfare Laboratory (USALWL), Aberdeen Proving Ground, (APG), Maryland, under Work Assignment No. 4, entitled "Camouflage Applications of Low Density Urethane," Task No. 22-C-72 of Contract No. DAAD05-72-C-0108. The work reported herein represents the results of a program initiated by the Applied Chemistry Branch under the technical supervision of Mr. Kenneth G. Carlon, originally and presently under Mr. John Larry Baer and Mr. Louis S. D'Elicio.

ABSTRACT

The purpose was to determine feasibility and effectiveness of a new camouflage technique using terrain matching, colored, urethane foam. The foam is sprayed directly on the item for permanent installation or indirectly on a polyethylene substrate cover draped over the item, from which it is readily removed. The items camouflaged are a variety of Army equipment and field installations to disguise, deceive, and confuse the enemy to gain tactical and strategic advantages.

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I. INTRODUCTION

This report describes the work performed by AAI for USALWL under Work Assignment No. 5, entitled "Camouflage Applications of Low Density Urethanes" of Contract No. DAAD05-72-C-0108. New and improved camouflage techniques are required to enhance the security of the U.S. Army in the field to disguise, deceive and confuse the enemy through his surveillance and other means of acquiring intelligence on our friendly forces.

The objective of this work assignment was to evaluate commercially available, portable, urethane foam spraying machines to apply disrupter-type camouflage in the field.

AAI procured two (2) portable urethane foam spraying machines for evaluation and a sufficient quantity of urethane foam materials to support a series of tests. During these tests, AAI determined the foam density required to produce a structural strength capable of withstanding normal environmental conditions, without the need for tie-downs. In addition, AAI procured a simple system whereby colored pigments were introduced into the foam material. The colors of interest in this program were limited to two (2) shades of green, light green and forest or dark green. During evaluation, the initial development tests were performed at the AAI facility until acceptance by USALWL. The equipment and foam material were shipped to various Army agencies and this new camouflage technique was successfully demonstrated in the field, by AAI personnel, at the agency facility.

The feasibility and effectiveness of this camouflage technique were proven during the formal demonstration in the "MASSTER" program at Fort Hood, Texas. The "MASSTER" personnel recommended that this camouflage technique be advanced into Phase II for additional development and include the militarizing of the spray equipment.

The major problems encountered were the continual clogging of the spray gun and the loss of quality in the foam's structure and the color due to the use of foam materials that had exceeded their six month shelf life by a factor of 3.

The following sections of this report describe the urethane foam materials, the spray machines, evaluation tests, demonstrations performed and the problems encountered.

NOTE: It is recommended that this report be used in conjunction with AAI Report No. ER-7155, dated July 1972, entitled "Operator's Manual for Camouflage Applications of Low Density Urethanes."

II. REQUIREMENTS

The requirements stipulated under this task were as follows:

A. Procure two portable urethane foam sprayers for evaluation.

B. Procure a sufficient amount of resin to conduct a series of tests to determine the density of foam required and the thickness required to produce a structural strength which can withstand normal environmental conditions with a minimum of tie-down.

C. Purchase or fabricate a simple system whereby a range of colored pigments can be introduced into the spray system. The color of interest for this portion of the program shall be limited to various shades of green.

D. For the system, prepare an operator's manual which will describe system operation, application techniques, maintenance and refilling instructions.

E. Conduct a series of tests at APG during which typical installations (mortar positions, bunkers, etc.) will be camouflaged using techniques evolved during the initial evaluation.

F. Provide the services of one engineer or technician for a period of one week at Fort Hood, Texas, to assist in a demonstration of the system.

G. Refurbishment of urethane spray machines to camouflage a jeep, at APG for photographic coverage of the camouflage technique.

III. SUMMARY OF WORK

Two portable urethane sprayer units, selected by the government's technical supervisor, were purchased for evaluation. In addition, 1100 pounds of material, prepared to generate foam having a density of 2 lbs/ft^3, were purchased. Careful consideration was given to the selection of the foam density, since procurement lead time was an important factor in the program's schedule. The selection proved to be a judicious one since the foam appeared suitable to all of the program's requirements. During the evaluation of the sprayer units, the supplier of the material experimented with pigmenting the resin component. After some initial difficulty he obtained a stable and compatible pigment which produced various shades of the selected color, green. The government's technical supervisor selected and approved two contrasting shades of green from a number of samples of green pigmented foam. These two shades were then applied to a storage building in order to attain the desired effect, as shown in the frontispiece. The spraying of this building also permitted both machines to be tested for continuous operation.

Individual tests were conducted to determine the build-up capability and the structural capacity of the foam. Plywood panels, 4' x 8', were mounted in horizontal and vertical positions and sprayed. Vertical panels were used to determine the adherence and foam build-up capaci . Horizontal panels, covered with polyethelene film, were used for making 4' x 8' rigidly self-sustaining panels of various thicknesses.

The Technical Project Officer (TPO) witnessed the application of light and dark green camouflage foam to the storage building at the AAI facility. During this operation, he observed the performance of the operator, equipment, the end result, and accepted the system. The machines, foam materials and accessories were delivered to USALWL for shipment to Fort Hood, Texas. On 25 July 1973, AAI personnel successfully demonstrated the camouflage technique in the "MASSTER" program at Fort Hood, Texas. The equipment was shipped from Fort Hood to USALWL. On 1 and 2 November, 1973, AAI personnel refurbished the equipment at APG and camouflaged a Jeep for more comprehensive photographic coverage of the camouflage procedural operations.

In addition to the above work, AAI prepared and delivered Report No. ER-7155 entitled "Operator's Manual for Camouflage Applications of Low Density Urethanes" in July 1972.

This work assignment was completed by the delivery of this technical report.

IV. DESCRIPTION OF URETHANE FOAM

A. Technical Data

This section outlines various parameters and operational data regarding the characteristics and performance of the urethane foam material used in this program.

1. Urethane foam is generated from the rapid exothermic chemical reaction caused by the mixing of two liquid components, which are designated as "A" and "B".

2. "A" is a polymeric isocynate and "B" is a polyol or resin, which contains freon gas in various amounts to control the foam expansion ratio and density.

3. A foam density of 2-lbs/ft^3 was selected and successfully used in this program.

4. The weights of the liquid "A" and "B" components are equal and weigh 10 lbs/gallon and their viscosities at 70^o are 400 cps and 250 cps, respectively.

5. The mix ratio of the "A" and "B" components are 1:1 and is controlled by the spray machine.

6. After spraying, the foam expands to a ratio of 30:1 and solidifies in a matter of seconds to produce a fine, closed cell, foam structure.

7. The color pigment is added to the B component only.

8. "A" and "B" components have a certified shelf life of 6 months.

9. The use of components that have exceeded their certified six-month shelf life results in loss of true color and fine cell structure. AAI used components 18 months old, 12 months beyond the 6-month shelf life and verified these results and also that the foam structural strength is reduced.

10. In storage the pigmented "B" component container should be turned over every 2 or 3 days to prevent separation of pigment. However, both components should be stored at room temperature, if possible.

11. If foam material is stored beyond the 6-month shelf life, it is mandatory that the "B" component in its container be thoroughly mixed on a mechanical shaker for a period of one-half hour prior to use.

12. The sprayed foam adheres permanently to most surfaces, except polyethylene film. Permanently applied foam can only be removed by sand-blasting.

13. For quick removal foam applications, the item to be camouflaged can be covered with a polyethylene drop sheet. The foam is sprayed directly on the sheet which is internally supported by the item. This approach protects the item from the foam, and allows improved disruption of the item profile. This procedure may also be used to fabricate camouflaged foam decoys, which may be removed from the item in one piece and deployed in the combat area to confuse the enemy.

14. The foam provides fringe benefits of insulation and waterproofing capabilities that are advantageous in certain camouflage applications.

15. The Model No. 20 machine uses pressurized nitrogen to spray the foam at a rate of 8 lbs/minute.

16. The capacity of the Model No. 20 machine used in this program is 20 gallons of foam components, 10 gallons of "A" in the tank coded red and 10 gallons of "B" in the blue-coded tank. The 20-gallon charge is capable of spraying an area of 800 ft^2 x 1" thick.

17. "Cello Solv" is the only known solvent for this foam and is used for cleaning the spray gun components.

18. As stated above, the "B" component contains freon gas, which, with its high expansion capability, could cause component overflow when filling the spray machine tank in ambient temperatures above 55°F.

19. The spray machine incorporates pre-heaters and hose heaters for each component to decrease their viscosities for improved flow and sprayed foam quality. The heating procedures assure the spraying of foam at lower ambient temperatures.

20. The "A" and "B" components stored in the spraying machines are usually pressurized at 150 to 200 psi to keep out moisture and other contaminents which can degrade the components.

21. Shipping containers for the components are sealed and should not be opened to the atmosphere until ready to use.

22. The foam spray from the gun degenerates in the rain and the spray is difficult to control in a windy environment.

23. The "A" and "B" components are deliberately kept segregated in the spray machine subsystems until they exit from the spray gun nozzle where they are mixed.

24. In this program, two-colored camouflage was applied - light green and dark or forest green. Since the pigments for each are added to the "B" component, two spraying machines were required, a machine for each color.

25. The environmental effects on the foam camouflaged storage building at the AAI facility were kept under surveillance since the foam

application 19 months ago. The building was initially camouflaged with the natural beige color and a few weeks later one sidewall was camouflaged with the two shades of green. (See frontispiece). After exposure to summer sunlight, the beige turned to a dark brown in 2 to 3 weeks, whereas the greens darkened towards an olive drab in 2 to 3 months. The outside surface of the foam became powdery, whereas internally the foam lost its fine cell structure and could be pulverized by rubbing a sample between the palms of the hands. It is noted that protective coatings which are commercially available may be sprayed on the foam to protect it from the weather. Applications of the foam improved the storage building by the foam qualities of insulation and waterproofing.

26. In this program, the "A" and "B" components were procured in 5-gallon, pour spout cans, which are color coded red for "A" and blue for "B". This approach facilitates handling and charging the machines.

B. Physical Properties

The following physical properties were obtained on foam samples produced by a vendor using a similar spray machine. His preheater temperature was 140°F and the hose temperature was 120°F. The foam samples were tack-free in 4 to 5 seconds, when sprayed at room temperature in a thickness of 1" to 2". A nominal 2-lb/ft^3 density was produced in the foam samples.

1. Compressive yield strength (ASTM-C-165-54)	
Parallel to foam rise	34.3 psi
Perpendicular to foam rise	13.8 psi
2. Closed cell content	> 90%
3. Water absorption (MIL-P-21929A)	.07 lbs/ft^3
4. Aged "K" factor (Btu/hr/sq.ft/°F/in)	.15
5. Aging characteristics (% volume change)	
200°F for 3 days	+8%
-20°F for 3 days	> +1%
140°F at 90% humidity for 7 days	+7.3%

The above data were generated under controlled test conditions and the supplier indicates that he cannot guarantee the same results to users of his materials under a variety of conditions.

V. DESCRIPTION OF SPRAYING MACHINE

The urethane foam spraying machine is a self-contained portable unit that requires a standard nitrogen bottle for pressurizing the liquid materials and a 30 amp, 220 VAC, single-phase electrical power source for its heating equipment. The flow of the materials through the various components is shown in the mechanical schematic of Figure 1.

The A and B components under 250 psi nitrogen pressure exit the bottom of the tanks into the preheaters. Here they are heated to 150°F. Upon leaving the preheaters they pass through the heated hose whose temperature is set at 120°F. The components then enter the gun where they are mixed at the spray nozzle. The materials have been carefully separated until they are sprayed from the gun nozzle.

The machine is composed of the following six groups:

- Pressurized tanks
- Pressure regulator
- Preheaters
- Heated hoses
- Control panel
- Spray gun

A. Pressurized Tanks

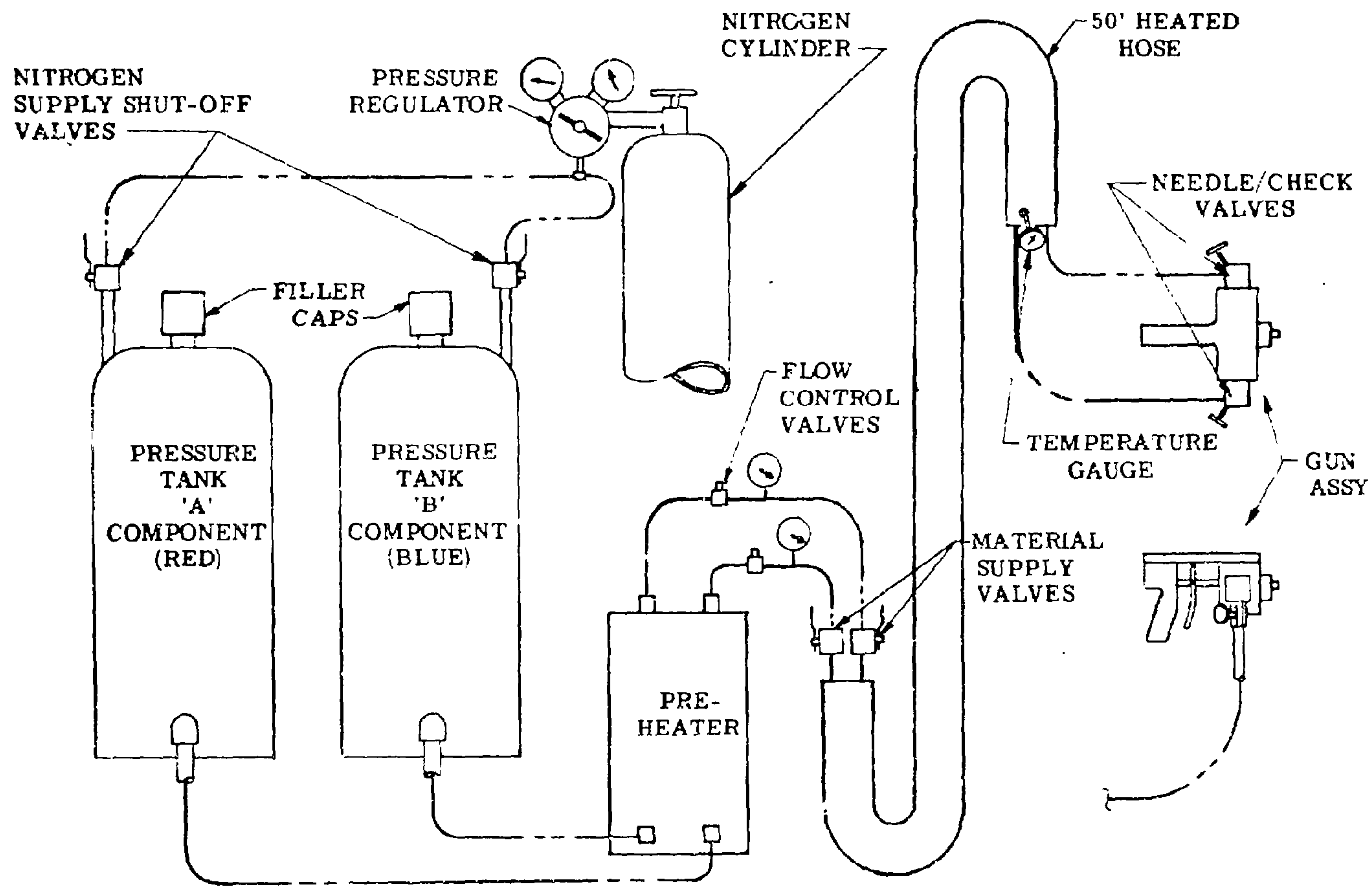
Two color-coded tanks are welded to a hand truck frame. They contain the separate liquid components of urethane foam under pressure: the red tank for the "A" component, polymeric isocynate; the blue tank for the "B" component, polyol or resin. Each tank holds approximately 100 lbs. of material or about 10 gallons each. The tanks are fitted with quick-release cam-locking filler caps (Figure 2, Item 4), and nitrogen inlet valves (Figure 2, Item 6), at the top, and material exit pipe fittings at the bottom. The tanks are rated at 500 psi working pressure.

B. Pressure Regulator

The pressure regulator group consists of a pressure regulator, high and low pressure gauges, pressure relief valve, and hoses. The inlet side of the pressure regulator has a No. 580 connector to fit a standard nitrogen bottle. The high pressure gauge indicates the nitrogen bottle pressure. The outlet side of the pressure regulator is teed into two hoses which attach to the inlet valves at the top of the tanks. The low pressure gauge indicates the outlet pressure from the pressure regulator to the tanks, while the pressure relief valve, set at 350 psi, protects the hoses.

C. Preheaters

The preheater group consists of two separate aluminum containers having heating elements at their centers. Foam components are preheated after leaving the tanks and before entering the heated hoses.



MECHANICAL SCHEMATIC

FIGURE 1

D. Heated Hoses

The heated hoses are 50 feet long and carry both preheated foam components separately from the preheater to the spray gun. This length permits the spray gun to reach a wide area of coverage without moving the tanks. The inner hoses are made from 1/4" I.D. extruded teflon tube covered with a stainless steel single-wire braid heater. The hoses are insulated from the tanks and spray guns by the use of plastic fittings. The stainless steel heaters are covered with armaflex insulation. Both of these hose assemblies are laid side by side and wrapped with wide fabric tape to form a single hose assembly. A stem thermometer, inserted through the insulation so that its sensor tip contacts the braided heater, is located near the gun end to indicate the house temperature.

E. Control Panel

The control panel (see Figure 3) contains the preheater and hose heater control knobs, indicator lights, and fuzes. The preheater control knobs on the left side of the panel are calibrated in degrees. Indicator lights above these knobs, when lighted, indicate that the set temperature for the preheaters has been attained. The large control knob on the right is a variable transformer (Variac) to control the voltage to the hose heaters. Percent of output voltage is set at this knob and adjusted until the proper temperature is noted at a thermometer near the spray gun.

F. Spray Gun

The spray gun (see Figures 4 and 5) has a pistol grip with a large enough trigger to engage all four fingers. The trigger is spring-loaded forward and actuates a valving rod which passes through the nozzle mixing body o open or close the spraying orifice. The nozzle is contained in a block forward of the trigger. On the sides of this same block are mounted the needle/check valves where the heated hoses terminate. The nozzle mixing body is made of teflon and its center and axial hole engages the valving rod. Its purpose is to mix the foam components just before they exit the cone orifice which is a separate teflon piece. The nozzle mixing body and cone orifice are retained in the block by a brass end cap.

NOTE: The above described machine, EZFOAM Model No. 20 and material EZ-45A, EZ-45B light green and EZ-45B dark green may be purchased from:

E.Z. Foam, Inc.
P.O. Box 244
McKean, Pennsylvania 16426

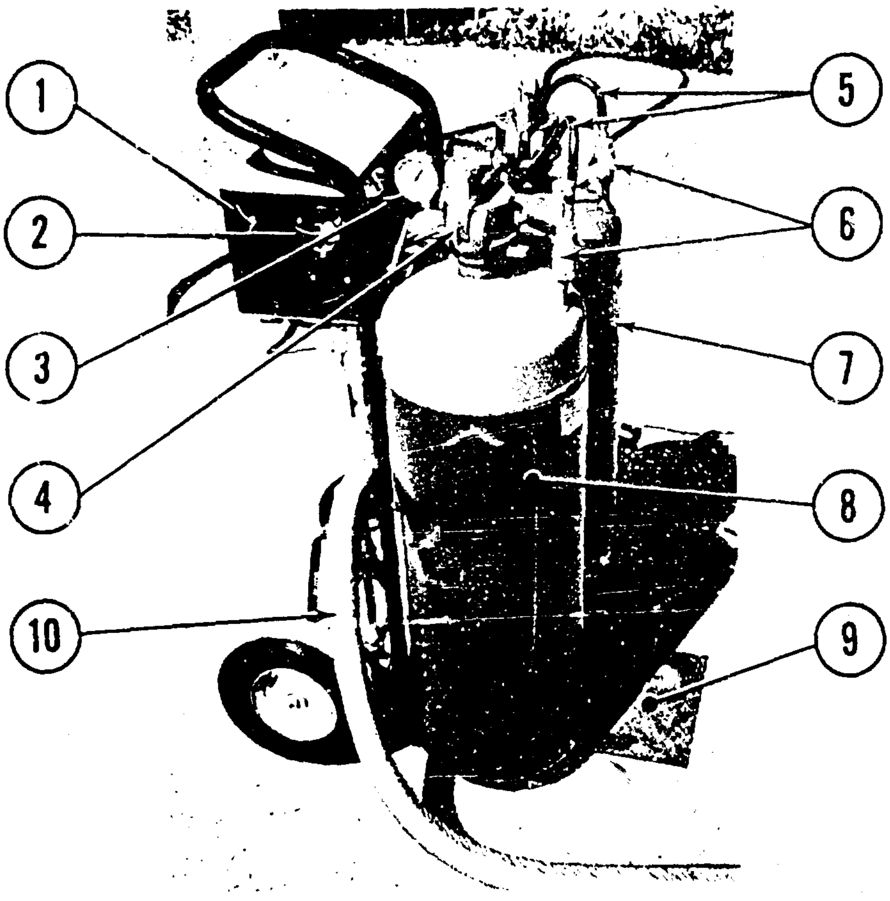


FIGURE 2

SPRAYING MACHINE - SIDE VIEW

(1) POWER SWITCH

(2) 220 VAC RECEPTACLE

(3) PRESSURE GAUGE - P/O PRESSURE REGULATOR GROUP
DISCONNECTED FROM NITROGEN BOTTLE AND RESTING ON TANKS

(4) QUICK RELEASE FILLER CAP

(5) NITROGEN SUPPLY HOSE - ATTACHED TO TANK & PRESSURE REGULATOR

(6) NITROGEN SUPPLY SHUT-OFF VALVE SHOWN IN CLOSED POSITION

(7) COMPONENT "A" PRESSURE TANK

(8) COMPONENT "B" PRESSURE TANK

(9) PLATFORM FOR NITROGEN BOTTLE

(10) HEATED HOSE

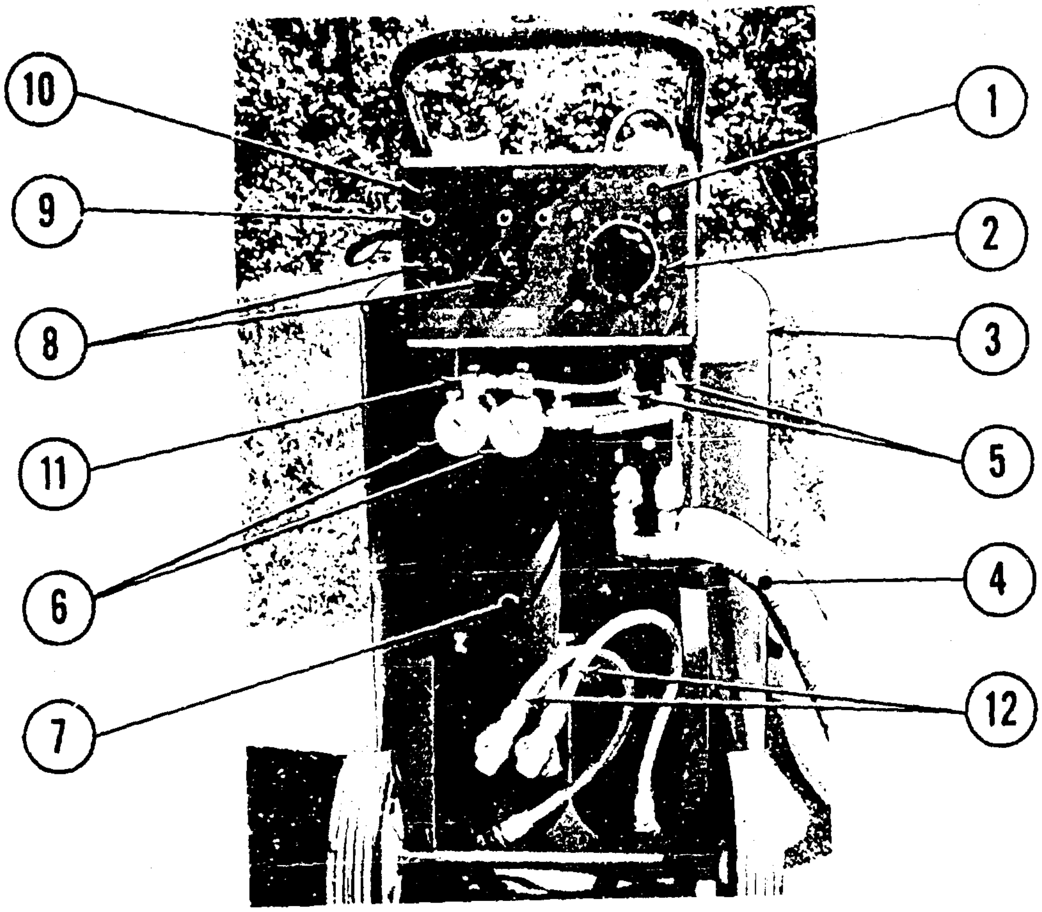


FIGURE 3

SPRAYING MACHINE - FRONT VIEW

(1) CONTROL PANEL
(2) VARIAC - HOSE HEATER CONTROL
(3) PRESSURE TANK - "B" COMPONENT
(4) HEATED HOSE
(5) MATERIAL SUPPLY VALVE
(6) PRESSURE GAUGES - COMPONENT PRESSURES
(7) PREHEATERS - COVERED WITH ARMAFLEX
(8) PREHEATER TEMPERATURE CONTROLS
(9) INDICATOR LIGHT - COMPONENT "A" PREHEATER
(10) FUSE - COMPONENT "A" PREHEATER
(11) FLOW CONTROL VALVE - COMPONENT "A"
(12) FIXED HOSE - PRESSURE TANK TO PREHEATER

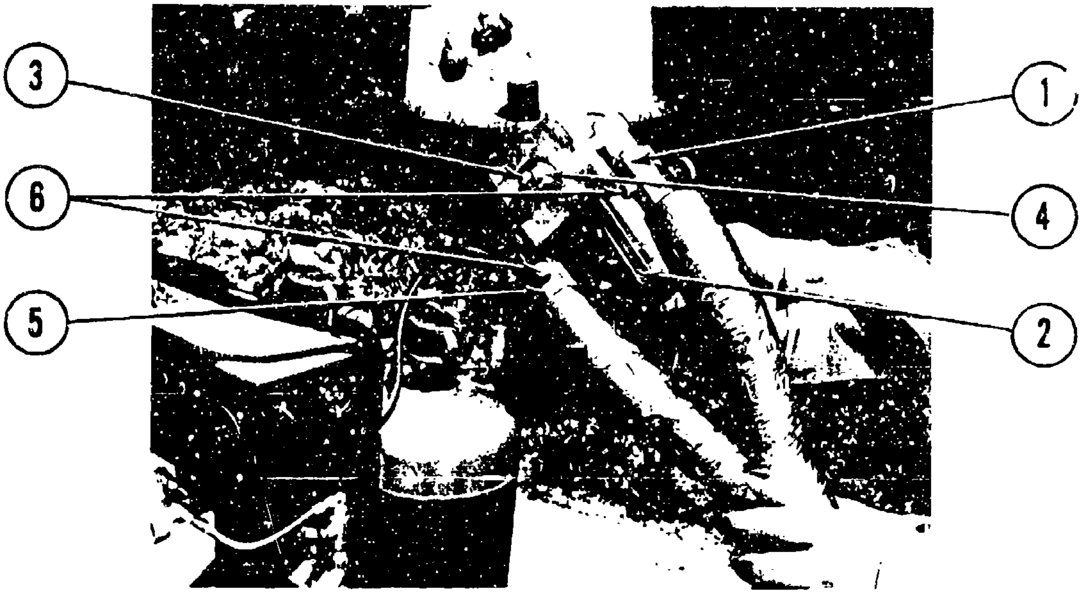


FIGURE 4

SPRAYING GUN ASSEMBLY

(1) NEEDLE/CHECK VALVE - COMPONENT "B"

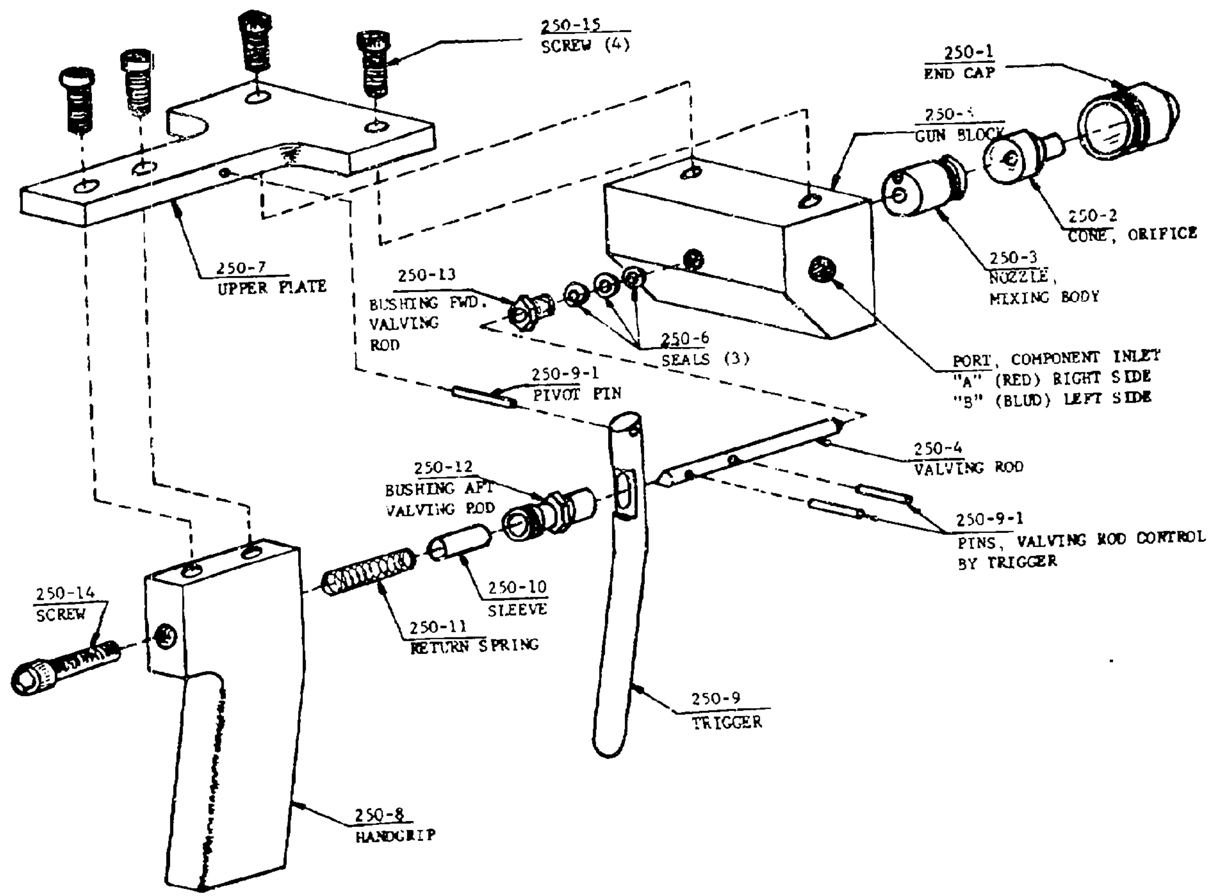
(2) TRIGGER

(3) NOZZLE ORIFICE

(4) RETAINING CAP - NOZZLE ORIFICE

(5) NEEDLE/CHECK VALVE - COMPONENT "A"

(6) PIPE CAPS - CHECK VALVE ACCESS



Spray Gun Disassembly Sketch

Figure 5

VI. PROBLEMS ENCOUNTERED

Five separate problems were encountered and solved during the progress of the testing program. The first three involved the spray gun; the fourth, the variac which controls the heated hose temperature and the fifth concerned the filling of the "B" component into the machine's pressurized tank.

A. Spray Gun

1. Nozzle.

The gun nozzle provides a mixing chamber for the two material components before they exit the gun in an atomized spray. Insufficient tightening of the nozzle retaining cap allowed premature mixing of the foam components which then clogged the nozzle orifice. The gun had to be disassembled and thoroughly cleaned with a solvent, Cello-Solv, before it could be made operational again. The cleaning process is a time-consuming, sticky, unpleasant task. Overtightening the retaining cap resulted in collapsing the nozzle mixing apertures and consequently the spray cone would degenerate into a stream. At this stage, the nozzle would have to be replaced and the cleaning process repeated. A just-sufficient tightening of the nozzle appeared unattainable until the vendor redesigned it.

2. Dropped Gun

The second problem was revealed when one of the spray guns was inadvertently dropped. In order to insulate the hose heater (a braided wire encasing the 50-foot hose) from the spray gun, plastic pipe fittings are used. These fittings when subjected to shock, break very readily. In order to replace them when broken, the material supply valve (see Item 5 of Figure 3) must be closed and an extractor, suitable to the fitting's I.D., is used to remove the two halves from the hose and gun. Since these tests were conducted, the vendor has replaced the plastic fittings with foot-long sections of rubber hose.

3. Trigger/Metering Rod

The third problem became apparent after the gun had been used for a period of several hours during which the gun was turned on and off numerous times and the nozzle had to be replaced at least two times. (See Figures 4 & 5 Section 5.F for a description of the gun). The trigger became stuck during the spraying operation and had to be pushed forward in order to close the nozzle orifice. The trigger is spring loaded forward in order to maintain the valving rod in the closed position. Although the valving rod is .005 larger in diameter than the hole in the nozzle in order to insure a sealing action, leakage occurred where the valving rod enters the nozzle housing block. Accumulation of foam material around the leakage area caused the valving rod to bind so that the force of the trigger spring could not overcome this added friction. A close examination of the valving rod revealed a surface finish of approximately RMS 63. Responding to the recommendation

that the surface finish of the rod be improved, the vendor replaced the rods in both machines with new ones having a polished surface. The operation of the trigger was noticeably improved. Although no extensive tests were conducted on the new rods, since they were inserted near the end of the program, it is believed that the improved surface finish will reduce considerably the cutting action on the teflon nozzle, and thereby extend both the useful life of the nozzle and time of non-leakage.

B. Variac

The variac controls the heated hose temperature. During one of test runs, the hose thermometer on one of the two spraying machines indicated that the heater failed to maintain a constant temperature on the materials; consequently, the cone of spray degenerated. Investigation showed that the spring which held a contact against the coil windings of the variac was missing. When the spring was added the problem was solved.

C. Filling

One of the most disconcerting problems arose during the filling of the storage tanks. The "B" component or resin foamed, causing the resin to overflow the tanks when approximately one-half full. This occurred when the ambient temperature was 68°F. A consultation with the vendor revealed that the resin was designed for low temperature use and that the freon used to generate the foam was responsible for the "boiling over." The vendor agreed to increase the additives that would prevent boiling of the pigmented material, which had been on order at that time.

VII. TEST AND DEMONSTRATION

A. Acceptance Test

During the operational check-out of the camouflage system equipment and the development of the colored foam, the TPO visited AAI on several occasions to observe the progress of the program. On 8 June 1972, the camouflage system acceptance test was performed at the AAI facility. During the acceptance test, the equipment and material were described and one sidewall of the storage building was camouflaged with the two foam colors, light and dark green, as shown in the Frontispiece. These tests were witnessed by the TPO and other government personnel. The TPO accepted the system and directed that all equipment, foam materials and accessories be delivered to USALWL for further demonstration. The system was rechecked, packaged and delivered to USALWL on 21 June 1972.

B. USALWL, APG, MD.

The TPO considered the camouflage system components to be in good working order for the requirement to demonstrate the system at Fort Hood, Texas on 1 August 1972. Therefore, he waivered the need for the APG demonstration and shipped the system to Fort Hood.

C. "MASSTER" Demonstration, Fort Hood, Texas

The "MASSTER" demonstration of this foam camouflage concept at Fort Hood was originally scheduled for the first week of August 1972. However, after several postponements by the Army, the demonstration was successfully performed from 8:00 to 8:30 A.M. on 25 July 1973.

A representative from USALWL and three from AAI visited Fort Hood from 23 through 25 July 1973 to retrofit the equipment and conduct the demonstration.

The items selected to be camouflaged were a 55-gallon drum, a wood bunker mock-up, prior to, and a jeep during the demonstration. Foam sprayed directly on an object becomes permanent, due to the adhesive characteristics of the foam. Therefore, a substrate of .002"-thick polyethylene sheet was draped over the item, staked down, and the foam was sprayed directly on the plastic drop cloth. The advantages of the plastic substrate are: it protects the item from direct contact with the foam; it assists the disruption of the item's configuration; and after spraying, the foam structure may be readily removed from the item and used as a decoy to confuse the enemy. All items at Fort Hood were covered with the polyethylene substrate prior to applying the foam.

The demonstration commenced at 8:00 A.M. on 25 July 1973, with an introduction and presentation of the system by the USALWL representative, while the AAI personnel stood by ready to spray the substrate covered jeep. The 55-gallon drum and its removed camouflaged foam structural form had been placed on the side of a hill about 200 yards away from the site, prior to the demonstration.

The USALWL representative pointed out the drum and its two-colored foam structure on the hill to illustrate the effectiveness of this camouflage approach. The previously camouflaged bunker mock-up was also described. After all the attendees' questions were answered, the signal was given and the jeep was camouflaged with the two-colored foam. After the jeep was camouflaged (in less than 15 minutes), a group of men lifted the camouflage foam structure from the bunker and placed it beside the original mock-up to show the decoy capability of the foam camouflage concept.

The demonstration attendees, consisting of about 35 Army officers from major to major general, examined the camouflaged displays and cut out small sections to examine the foam structure. The comments overheard from the attendees on this camouflage concept and its potential battlefield use were very favorable. The attendees indicated that the camouflaged displays were very good, the basic light green (No. 2 machine) and the blotches of dark or forest green (No. 1 machine) blended well with the Fort Hood terrain. In the de-briefing, we were informed that "MASSTER" will forward a letter to a higher command, recommending that this camouflage concept be accelerated into a Phase II development program, including the militarizing of the equipment.

Due to the favorable comments received on the concept at the demonstration site and during the de-briefing conference, it was concluded that the demonstration was very successful.

In the days preceding the actual demonstration, several problems were encountered with the clogging of the spray guns and the use of foam material that had exceeded its 6-month shelf life by 6 months. The "B" components, containing the pigment were mixed on a mechanical shaker prior to use, resulting in the end product foam camouflage colors approaching the original true colors. The "MASSTER" personnel observed and are aware of the problems encountered on the spray machines; however, they indicated that the end item foam camouflage was impressive and the spray machine deficiencies are correctable.

D. USALWL, APG, USA

After the "MASSTER" demonstration at Fort Hood, the equipment was returned to USALWL. It was determined that the resulting photographic coverage of items camouflaged at Fort Hood was inadequate for its intended use. AAI was requested to put the equipment in operational condition and camouflage a jeep for detailed coverage of the process. The parts required for retrofit were procured and the work was completed at APG on 1 and 2 November 1973. The spray gun problems encountered at Fort Hood re-occurred; however, the equipment was finally put in working order by reworking the "A" and "B" mixing nozzle. The urethane materials used in this operation were the natural "A" and the light and dark green "B" components delivered to USALWL by AAI on 21 June 1972. The material was 17 months old, which is 11 months beyond its certified 6-month shelf life and probably contributed to equipment problems. The "B" components were not mixed on a mechanical shaker prior to use in this operation to improve the end colors.

The Jeep was positioned, covered with a polyethylene substrate and camouflaged. The light green was sprayed on first and the dark green blotches were then sprayed to obtain the blending effect.

The jeep _before_ camouflage is shown in Figure 6 and the jeep _after_ camouflage is shown in Figure 7. The light green color in Figure 7 appears to have reverted back to the natural beige foam which shines due to the reflection of the sun. The dark green is considerably darker than its original shade. These results may be due to the fact that the 17-month old pigmented B components were not thoroughly mixed in a mechanical shaker prior to use. The colors produced in Figure 7 should be compared with the corresponding colors shown in the Frontispiece. The color foam applied to the storage building in the Frontispiece was about one week old.

Figure 6. Jeep with Polyethylene Before Camouflage.

Figure 7. Jeep After Camouflage

VIII. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

Effective camouflage is a valuable weapon to be used in both tactical and strategic operations of conventional, unconventional and nuclear warfare to gain advantage over enemy forces. Camouflage is used to deny the enemy information as to location and strength; fool the enemy by deception; and to mislead him by misrepresenting the true identity of an installation, an activity, or an item of equipment. Good camouflage is achieved by the effective use of dispersion, hiding, disguising and deception principles.

The colored urethane foam - camouflage concept described herein, has been proved feasible and incorporates qualities to achieve the effective camouflage principles stated above. The system was successfully demonstrated at Fort Hood, Texas before high ranking U.S. Army Officers and at USALWL, APG, Md., and it was mutually agreed that this concept has great potential in the field of camouflage, which seems to have been neglected for several years.

As a disrupter type camouflage, sprayed urethane foam appears to be ideally suited. The sprayed foam is extremely sticky and readily adheres to most materials including itself. This latter characteristic allows the foam to be built up in regular or irregular mounds or ridges to provide a disrupter type camouflage as needed. The foam sets up quickly and can be made in large self-supporting sheets which can be stripped from polyethylene film used as a mold release, since urethane foam will not adhere to polyethylene. Vehicles such as cars, trucks, or tanks, as well as permanent and semi-permanent structures, can be draped with cloth or plastic film which, when coated with urethane foam, provides a self-supporting disrupter type camouflage.

The end product, the sprayed colored urethane foam, provides effective camouflage capabilities; however, the spray machine has shortcomings and the raw foam materials have certain undesirable environmental and storage characteristics. The spray machine and the present foam materials will actually achieve the camouflage mission, but require an excessive prior effort to put the spray machines in working order. The primary problem is the unreliable performance of the spray guns. The following section offers a list of improvement recommendations that should be investigated and incorporated in the system in order to militarize the equipment and material for Army use.

It is concluded that Phase I of the "Camouflage Applications of Low Density Urethane" exploratory program has been successfully completed.

A summary of the system advantages and disadvantages is listed as follows:

1. Advantages

a. End product produces effective camouflage.
b. Foam adheres to most known materials
c. Applied foam expands to a 30 to 1 ratio.
d. Foam sets up within 5 seconds after spraying.
e. Foam sprayed on a polyethylene film substrate covering the item may be readily removed as a unit and used as a decoy.
f. Foam provides insulation, waterproofing and flotation qualities.
g. Low density foam 2 lbs/ft^3 is lightweight and rigid.
h. Foam provides excellent disrupter type camouflage, since it will readily form irregular foamed shapes on any item profile. Irregular foamed shapes may be built up to heights of 12" or more and are self supporting.
i. One operator, with a model 20 machine with a 20-gallon charge (200 lbs.) of foam components, can spray an 800 ft^2 area x 1" thick in about 12 minutes.

2. Disadvantages

a. Foam will not form spray in rain.
b. Foam cannot be sprayed and controlled in windy weather.
c. Sunlight darkens foam colors within 2 to 3 months.
d. Foam disintegrates in time when exposed to the elements. After 19 months, foam surface becomes powdery and remaining foam thickness sample remains hard but may be pulverized by rubbing between the palms of the hands.
e. Raw foam materials are too sensitive to temperature.
f. Foam storage requirements are a problem, especially the pigmented "B" component.
g. Applied foam requires weather protection spray for increased life.
h. 6-month shelf life of foam raw materials.
i. Spray gun performance is unreliable.
j. The spray machine with its nitrogen cylinder installed weighs 450 pounds, which is excessive and reduces system mobility.

B. Recommendations

This section outlines a series of improvement recommendations based on AAI's experience with the colored foam camouflage system, during the performance of this program. The feasibility of these improvement recommendations should be investigated and those found acceptable should be incorporated into the system. It is anticipated that this work can be achieved in a future Phase II program to militarize the system equipment and raw foam materials for ultimate Army use.

1. Urethane Foam Materials

Study raw materials and applied foam to improve the following factors, without impairment of existing foam camouflage effectiveness.

a. Increase 6-month shelf life of raw materials.
b. Decrease temperature sensitivity of raw materials.
c. Determine pigmented material effect on spraying operation.
d. Increase storage temperature range.
e. Eliminate need for periodically turning over pigmented "B" component while in storage and for mixing "B" component in a mechanical shaker to assure improved pigment distribution prior to use.
f. Determine if color can be added at the spray gun nozzle mixing chamber in lieu of mixing the pigment in the "B" component.
g. To retain true color and the closed cell structure of applied foam, it is recommended that the surface be sprayed with weatherproofing paint for protection against exposure to sunlight and other environmental elements.
h. To assure good end product foam, it is recommended that components which have exceeded their certified shelf life not be used.

2. Model 20 Spray Machine

The feasibility of the following recommendations should be investigated for incorporation into the improved spray equipment:

a. Redesign gun for reliable spraying performance.
b. Redesign to reduce 450-pound weight of spray machine.
c. Redesign equipment for "self-contained" spray machine unit by eliminating need for electrical and pressurized nitrogen power sources.
d. Investigate the use of explosive gas cartridge to pressurize "A" and "B" component tanks in lieu of pressurized nitrogen cylinders and controls.
e. Investigate use of multi-fuel heaters and other means to eliminate need for electric powered preheaters and hose heaters.

f. Determine feasibility of introducing color pigments at the spray gun nozzle-mixing chamber in lieu of premixing pigment in "B" component. If feasible one or more color pigments introduced, in turn and use the more economical natural "A" and "B" components. One operator, with one spray machine will be capable of introducing one or more color pigments in sequence for improved camouflage effect at a lower cost.

g. Gages or other means should be installed on two tanks to indicate the level of the components at all times. To prevent material waste, the operator should not refill the tanks until they will accept a full 5-gallon can of material.

h. Elimination of the pressurized nitrogen cylinder, shut-off valve, regulator, hoses, and shut-off valves on the tanks by a successful gas generator cartridge will reduce equipment weight by 165 pounds.

i. The use of multi-fuel heaters will eliminate 50-foot power cable, heaters, control box, variac, insulated joints, etc. It is estimated that a differential weight saving of about 30 to 40 pounds will be realized.

j. The above combined with other weight saving ideas to be developed during the militarized program could reduce spray machine weight by half or 225 pounds and would facilitate handling.

k. The spray machines, materials and accessories should be truck-mounted for mobility.

l. The need for tools and accessories should be minimized or eliminated by redesign of certain appropriate machine areas.

3. Foam Application Procedures

It is recommended that the procedures for spraying foam in camouflage applications be reviewed. The differences in approach may seem insignificant; however, one approach may have advantages over the other for military use and should not be overlooked.

a. Existing Approach Procedures

(1) The existing approach procedures described herein use color pigments mixed into the "B" components and a spray machine is required for each color or shade. In this case, two shades of green were used requiring two spray machines and operators. The light green was initially applied and the dark green blotches were then applied in irregular patterns to blend with the terrain. The next step was to spray the weatherproofing paint on the surface of the applied foam to protect it from exposure to sunlight and the elements. This last step is considered mandatory to retain the true color and the foam structure over longer periods of time. The last step was not performed during this program.

(2) The disadvantages of this approach are listed below.

(a) Pigmented "B" components are more costly than natural.

(b) Pigmented "B" components require periodic (2 to 3 days) turnover of their container during storage and shaker mixing for 1/2 hour duration prior to use. If this task is not performed the original true foam color will not be achieved.

(c) One spray machine required for each foam color applied.

(d) Pigmented "B" components cause spray gun clogging and malfunctions. Other foam spray machine suppliers, contacted by AAI, <u>will not add pigment to their "B" components</u> for the same reason.

(e) Spraying foam with pigmented components seems to be an efficient approach. However, the clogging of spray gun causes excessive equipment down-time and the application of the weatherproofing paint to the foam is an additional and separate operation.

(f) The logistics to support this approach may be excessive when consideration is given to the great number of colors and shades of colors that will be required to blend with the background color types of the various terrain throughout the world where the Army fights. The number of different color types of pigmented "B" component required is equal to the number of colors and shades selected to match the various types of terrain in different parts of the world. The other part of the logistics problem will be the delivery of the proper pigmented "B" components to the correct area of the world.

b. Improved Approach Procedures

(1) This approach uses the standard natural "A" and "B" components without color pigments, in the same spray machines. The natural foam is sprayed on the item to be camouflaged and the appropriate colored weatherproofing paints are sprayed on the applied natural foam in a second operation to obtain improved camouflage effectiveness and longevity. The number of operations are two, the same as the existing approach.

(a) Natural foam components are more readily available and economical to procure than the special components with pre-mixed color pigments.

(b) The natural foam components have improved "in storage" qualities and do not require the container turnover or mechanical shaker to mix the pigments as in the case of the other approach.

(c) A single spray machine with natural foam is more flexible for field use, since in this approach the same foam is sprayed on all items to be camouflaged, rather than restricted to the application of one color as in the existing approach.

(d) Since the weatherproof paint has to be applied, in any case, the required colors are added to the paint in this approach.

(e) The weatherproof paint colors will remain true for possibly two years or more when exposed to sunlight and the elements which is not true for the existing approach with the pigments mixed in the "B" components. <u>LUSTERLESS PAINT WILL ELIMINATE CHARACTERISTIC SHINE OF FOAM</u>.

(f) The colored weatherproof paint will also extend the life of the fine closed cell foam qualities.

(g) The spray gun will function more reliably. The reason is that the pigments which continually clog the gun are not being forced through the gun with the "B" component, as in the case of the existing approach. The lack of pigments in the foam of this improved approach will reduce the equipment down time, which has been intolerable on the existing approach.

(h) The logistics to support this new approach will be reduced considerably when compared with the existing approach and its pigmented foam. In the new approach, the standard natural color foam can be readily procured and at a lower cost. The foam will be standard for use throughout the world, regardless of background colors of the various terrain. The terrain matching colors, which may be many, will be processed into the weatherproof paint and the proper color or shade will be shipped to the appropriate parts of the world.